

TECHNICAL NOTE

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SUMMARY

The control of competing vegetation is an important operation in the establishment of young trees, and appropriate herbicide application can be a cost-effective weeding solution. Although the use of herbicides is now well established in forestry practice, manual methods of application still predominate. Mechanised spraying methods used in agricultural applications can be adapted to work in forestry situations. This Technical Note outlines these application methods and provides details on the components of mechanised sprayers and herbicide delivery systems. Information is also provided on pre- and post-storage maintenance, sprayer testing and spray drift management. Conclusions and recommendations give guidance for the use of mechanised sprayers in forestry.

INTRODUCTION

The use of herbicides for controlling competing vegetation is a widespread practice for forest establishment on weedy sites. Manual application methods have predominated because the prevailing terrain and operating conditions in forestry situations can restrict the use of standard agricultural spraying equipment. However, recent improvements in tractor technology and spraying systems offer woodland managers a wider choice of weeding methods.

Mechanised spraying systems for use in forestry are usually developed from models used in agriculture. They use a series of nozzles spaced equally along a boom and usually have a height adjustment system. The specific height varies with nozzle spray angle and spacing.

This Note describes the components of mechanised boom spraying systems and their application. Some components increase the sophistication of the system and are designed to deliver target volume rates as operating variables change. Other components are designed to reduce environmental and operator contamination and improve operator ergonomics.

APPLICATION METHODS

Herbicide can be applied in a number of ways:

- Overall: application over the whole treatment area.
- Band: application in a band over or between crop trees.
- Spot: application to an individual spot or around a tree.

- Directed: application to hit a target weed and to avoid crop trees.

Standard mechanised spraying systems deliver overall and band applications. Mechanised spot application is possible but requires a specially designed sprayer. Accurate directed applications are not possible.

The majority of spraying equipment operated by the agricultural industry uses pressurised hydraulic (water based) spraying systems. This equipment can be used for:

- high volume application (HV): greater than 700 l/ha.
- medium volume application (MV): 200 to 700 l/ha.
- low volume application (LV): 50 to 200 l/ha.
- very low volume application (VLV): 10 to 50 l/ha.
- ultra low volume application (ULV): less than 10 l/ha.

Tables 1 and 2 illustrate some of the advantages and disadvantages of manual and mechanised operations, and high and low pressure spraying operations.

FACTORS AFFECTING PRODUCTIVITY

A number of factors influence the work rate of boom spraying:

- **Speed of the prime mover.** This is in turn influenced by ground conditions which affect boom stability, turbulence and deposition, especially as speed increases.

Table 1 Advantages and disadvantages of manual and mechanised boom spraying operations.

System	Advantages	Disadvantages
Manual	<ul style="list-style-type: none"> • Low capital cost. • Suitable for small areas. • Less complex. • Suitable for post-plant spraying where guarded application is desirable. • Can be used on sites with irregular spacing. • Within reason, can be used on sites with obstacles or poor machine access. 	<ul style="list-style-type: none"> • Low output rates. • Not suitable for large areas pre- or post-plant programmes. • Operator can be exposed to contamination with some systems. • Operator ergonomics can be less than optimum.
Mechanised	<ul style="list-style-type: none"> • High output rates. • Suitable for large areas. • Can make the best use of limited weather 'windows'. • Potential for reduced operator contamination. • Improved operator ergonomics. 	<ul style="list-style-type: none"> • Not suitable for small areas. • Can be restricted by terrain and other site conditions. • High capital cost. • Not suitable for post-plant applications where guarded application is essential.

Table 2 Advantages and disadvantages of high and low pressure spraying systems.

System	Advantages	Disadvantages
Low pressure	<ul style="list-style-type: none"> • Relatively inexpensive. • Lightweight. • Multi-role use. • High outputs. • Usually low volume: a single tankful can cover a large area. 	<ul style="list-style-type: none"> • Cannot adequately penetrate and cover dense foliage due to their low pressure and usually low volume. • Most use hydraulic agitators so wettable powder formulations often settle out. Mechanical agitators can be a solution.
High pressure	<ul style="list-style-type: none"> • High pressure sprayers are useful for many roles. • Adequate pressure to direct spray through heavy vegetation. • Durable and reliable construction. • Standard piston pumps resist wear from gritty or abrasive materials. • Standard mechanical agitators keep wettable powders in solution. • Can be used with long hoses for remote targets. 	<ul style="list-style-type: none"> • Strongly built, can be heavy and costly. • Can use large amounts of water. • Pesticide can be misdirected, causing drift and off-target contamination.

- **Boom width.** Increasing the width of the application strip reduces the number of passes required to cover an area thus increasing the productivity of the sprayer. However, it is more difficult to keep wider booms level and at the correct spraying height.
- **Spray management systems.** Within defined parameters, travelling speed can be matched to site conditions, which can improve output in easier travelling conditions.
- **Spray volume.** Using low application rates will reduce the frequency and duration of re-filling, increasing productivity. However, lower-volume application rates may reduce efficacy in some conditions.
- **Availability of water.** A system for supplying the required water volume at the site is essential for re-filling efficiency.
- **Tank capacity.** The dimensions of the tank are limited by the space available and the load capacity of the prime mover.
- **Maintenance.** The length of breaks during spraying.

A basic sprayer relies on a set forward speed being maintained at a set pressure for an accurate application rate. Spray management systems fitted to sprayers can detect changes in travelling speed and adjust mixing rates and/or operating pressures to maintain the correct volume rate. However, increasing the spraying pressure reduces the droplet size, which can lead to a risk of increased drift. Spray management systems can compensate for slight variations in speed, but they must not be expected to cope with extreme variations. High forward speeds can result in poor crop penetration and greater turbulence behind the sprayer leading to potential drift problems.

Mechanised spraying systems for forest use must be strong, reliable and adequately guarded. Protecting exposed components is especially important to reduce downtime caused by damage and breakdowns.

COMPONENTS OF A BOOM SPRAYER

Boom transport

Spraying equipment can be fitted to a range of powered prime movers. Agricultural tractors, forwarders, specialised off-road vehicles and ATVs have all been used in forest weeding operations.

Forestry prime movers should have four or multi-wheel drive and be guarded for use on rough ground. Traction aids such as wheel chains and bandtracks may be required for improved grip and flotation. Boom sprayers can also be trailed or built as a specialised or self-propelled vehicle.

Cab ergonomics

The operator's cab should be air-conditioned and the system fitted with air filters to intercept herbicide drift, providing controllable and clean working conditions. The controls for the sprayer should be within the cab of the tractor. No pipes containing herbicide should enter the cab.

Boom suspension and stability

The boom sprayer (Figure 1) is designed to hold a number of nozzles at a pre-determined spacing pattern. Depending on the system and nozzle holders used, some adjustment of nozzle spacing is possible. The boom system should:

- Keep the nozzles at the correct height at all times.

- Be adjustable to meet tree crop/nozzle height needs.
- Have a safety break-back system to avoid damage from contact with the ground/tree stumps.
- Be capable of folding for transportation.

The boom break-back folding and height adjustment systems should preferably be controlled from the cab. This will reduce the potential for operator contamination and assist with the negotiation of obstacles, improving output and reducing sprayer system damage. For forest use, nozzle adjustment to match variable row spacing is essential in some conditions.

Boom stability is governed by machine and boom suspension. Irregular movement of the boom reduces the accuracy of the spray pattern. Improved boom stability gives a more uniform spray pattern and more sophisticated suspension systems enable rougher ground to be sprayed. The backward and forward swing of the boom, known as yawing, can result in under-application on the forward swing and over-application on the backward swing. The falling and rising of the boom, known as rolling, also disrupts the spray pattern, resulting in over- and under-application.

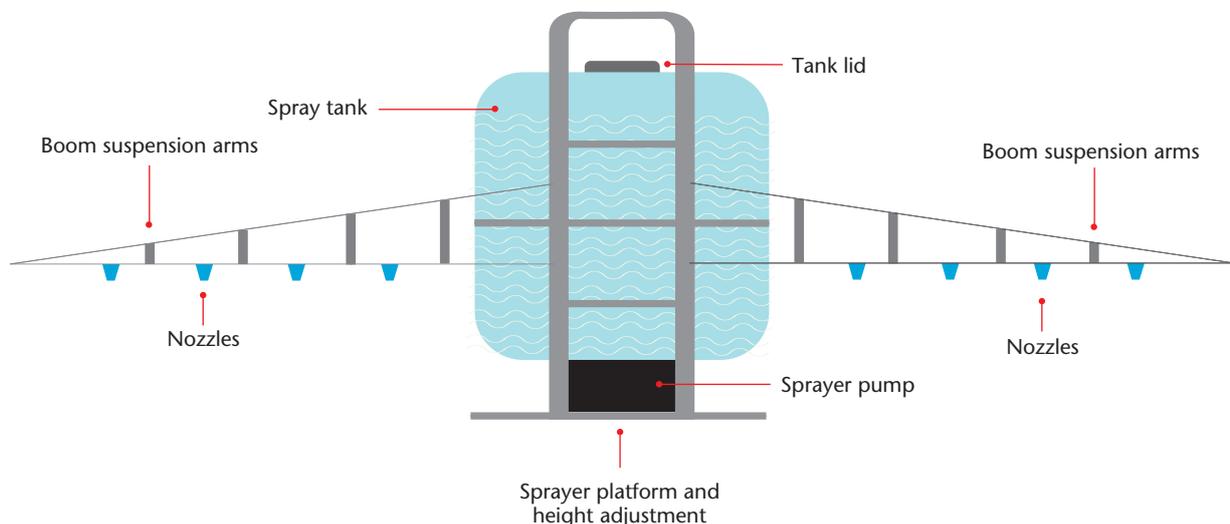
Sprayer components

Tank

The tank should have sufficient capacity to enable an extended period of spraying, reducing the frequency of re-filling. It should have a sight gauge (and preferably a cab-

Figure 1

Typical structure of a boom sprayer. Boom width can range from 6–24 m; capacities of spray tanks range from 200–3000 litres, or more where multiple tanks are fitted.



mounted tank level gauge) so that diluent level can be assessed. The lower section of the tank should have a sump to ensure that the herbicide mixture (or water with direct injection systems) is directed to the delivery system without interruption. An agitator should be used to maintain the homogeneity of the mix.

The tank should also be partitioned with baffles to reduce liquid surge, which will improve machine stability and reduce the creation of foam caused by mixture agitation. Tank protection and design should be adequate to prevent spillage if the vehicle overturns.

Pump

The pump must be reliable and resistant to corrosion caused by herbicides. It should have an output capacity 20% to 25% higher than that required, so that it is not working at maximum capacity, which can lead to accelerated wear and overheating. Three types of pump are available, diaphragm (most common), piston and centrifugal. Table 3 identifies pump characteristics.

Filters

Filters are essential to trap unwanted particles and help prevent nozzles and pumps becoming blocked. They are usually situated at several different points in the spraying system: at the filler opening, on the suction line; between the pump and the pressure regulator or in the nozzle body. Filter aperture size is between 0.08 mm and 1 mm (20 to 200 mesh – the number of openings per linear inch). Larger filters are installed downstream from the pump, and become increasingly fine nearer the nozzles. Nozzle filters should have smaller openings than the nozzle orifices themselves.

Control systems

Components for controlling flow and pressure include on/off valves, gauges and pressure regulators. A constant pressure at a specified setting is an indicator that the sprayer system is working satisfactorily. The operator should therefore be able to read the pressure gauges and operate the control valves from inside the cab. Figure 2 shows the components of a modern mechanised spraying system.

The sprayer must be calibrated before the start of operations, checking the variables of swathe width (controlled by height) and travelling speed. Travelling speed is affected by site conditions and spray management control systems should be adjusted so that the flow of herbicide matches this speed.

Figure 2 A model of a modern mechanised spraying system.

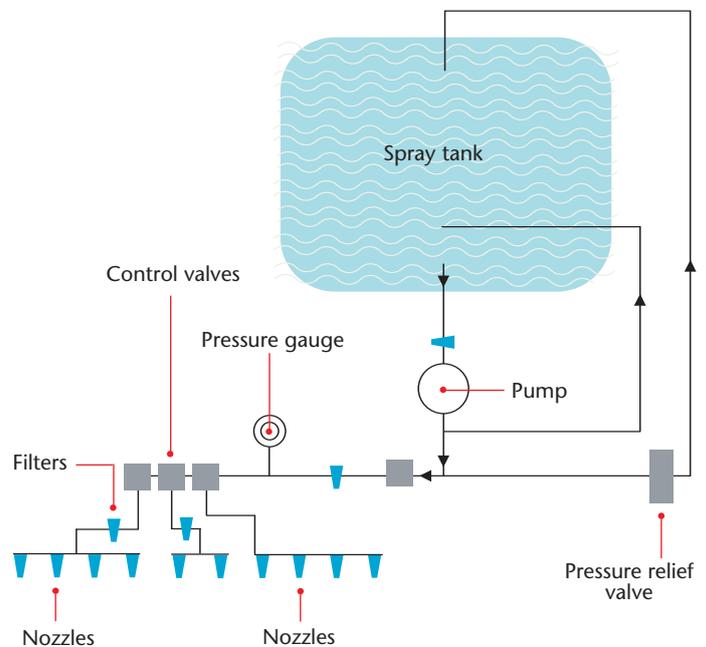


Table 3 Characteristics of pumps suitable for spraying systems.

Characteristic	Diaphragm	Piston	Centrifugal
Pressure (bar)	40	50	5
Maximum flowrate (l/min)	360	80	500
Relative durability	High	Low	High
Relative cost	High	High	Medium
Displacement where used	Positive	Positive	Not positive
Formulation types	All	Not wettable powers	All

The following formula can be used to calculate the required pump capacity:

$$\frac{\text{Rate of application (l/ha)} \times \text{width of strip required (m)} \times \text{speed (km/h)}}{600} + \text{Capacity required for hydraulic agitator (l/min)} = \text{capacity (l/min)}$$

If a system cannot match herbicide flow rate to travelling speed, the travel speed used for calibration must be maintained to give a uniform rate of application. This may be very difficult to achieve in forestry conditions.

Pressure control systems

A pressure relief valve ensures that the spraying system does not operate at a pressure in excess of set values identified by calibration. The device consists of a spring that holds the valve closed and a threaded spindle, which enables adjustment of the spring tension to control the pressure setting.

Other pressure control systems have by-pass valves or orifices which allow excess pressure from the boom to dissipate. For these types of control systems to be efficient, it is important that the forward speed of the prime mover is kept constant.

Spray management control systems

A number of more advanced control systems use electronic or mechanical means to regulate the output of the sprayer relative to changes in travelling speed. Without a spray management control system, the operator must work at a predetermined forward speed, maintained across the whole site.

The use of electronic spray management control systems is strongly recommended. This 'black box' approach gathers information from speed and output sensors and information from the operator above swath width and spray volume rate. These variables are monitored and instant calibration can take place to match sprayer output (herbicide concentrate and diluent) with travelling speed to achieve the required volume rate.

A spray management control system is an important accessory which enables the operator to use the optimum forward speed for the terrain, while maintaining the correct volume rate. The system supplies information on speed, output, pressure, volume rate, total spray used, area covered per hour and total area covered.

Direct injection systems

Direct injection systems use separate tanks to store the water and herbicide. Water is delivered at a controlled rate, and a metered rate (related to travel speed) of herbicide is injected into the water close to the nozzles. With the water and herbicide concentrate stored in

separate tanks and mixed just before application, the system reduces the volume of stored mixed spray solution; it also reduces the risk of error and spillage at the mixing stage.

Closed transfer systems

Closed transfer systems can use standard or purpose-built herbicide concentrate containers to store, mix, and in some cases measure, herbicide concentrate. They are designed to prevent operator and environmental contamination, which can take place through spillage when herbicide containers are used to manually transfer concentrate into storage tanks. In some systems, containers (cleaned by the transfer system) can be returned to the manufacturer for refilling. Future European legislation may influence developments in recycling. Reusable packaging may result in reduction of sprayer filling times, disposal costs and operator and environmental contamination.

Product choice for these systems is currently limited and available systems are more suited to high volume agricultural products. Some of the systems do not cater for all formulations.

Additional equipment

Low level induction devices

Low-level (height) induction hoppers or bowls made from metal, plastic or fibreglass are fitted to the side of all new sprayers and should be considered for retro-fitting to older ones. They enable the operator to add herbicide to the spraying system without climbing onto the machine. Models are also available for free standing use at filling points or for use with water bowsers. The herbicide is poured into the bowl and water is added to flush the bowl and carry the herbicide to the spray tank. A rinsing nozzle is usually fitted inside the bowl to wash empty herbicide containers. Induction devices are raised during spraying and lowered to about 1 m above ground for herbicide transfer.

Storage for personal protective equipment

Temporary storage for clean personal protective equipment (PPE) should be provided on the spray application vehicle for use by the operator in case of any problems or emergencies that may arise during spraying operations.

Sprayer decontamination

Modern sprayers carry separate tanks of clean water, tank rinsing systems, hand lances and brushes to enable

sprayers to be decontaminated before leaving the site. These systems can also be used to wash operator PPE. Hand-washing facilities are also available on modern machines.

Swath marking

Foam markers are particularly useful for pre-emergence sprays, but they are less reliable than tramlines at the correct spacing. Using foam markers requires extra operator vigilance especially when using a wide boom. Dye markers are an alternative to foam. Some dye markers are specifically named on product labels but few are designed for use at the volume rates commonly applied in forestry (Brown *et al.*, 2002).

HERBICIDE DELIVERY SYSTEM

Nozzle function and fitting

Nozzles play an important role in herbicide delivery. A number of nozzles are available for a range of spray patterns, flow rates and pressures to match site and application variables. In forestry, large volumes of water are generally used to obtain adequate coverage, therefore nozzles that handle large flows at low to medium pressures are more suitable. It is always advisable to check that nozzle type is suitable for the product, crop and target application rate.

The size and arrangement of the nozzles, the form of the spray pattern and the operating pressure will determine the size of droplets, trajectory, coverage and rate of application. The number and characteristics of nozzles must be matched to the capacities of the sprayer pump and tank.

Nozzles can be made of stainless steel, brass or plastic. Nozzle wear can be identified by an increase in flow rate, often indicated by a slight drop in system pressure and a deterioration of the spray pattern. Nozzles should be changed when their flow rate (compared with new) increases by 10%.

Screw or bayonet fitting mechanisms are generally used to attach hydraulic nozzles to the caps within the seating bodies, which are connected to the boom herbicide supply pipes. Multi-head bodies with rotating caps facilitate quick nozzle changes. Self-aligning caps ensure that nozzles are always fitted in the correct alignment, relative to the boom, with appropriate offset to avoid interference between adjacent fan nozzle spray patterns. Diaphragm check valves (DCV) are usually fitted to the nozzle bodies,

to prevent herbicide drip from the boom and to ensure a quick non-drip start and stop of herbicide spray in response to operator control.

Nozzle types

All nozzles are designed to give a set spray pattern and droplet size at a particular pressure and working height.

The hydraulic pressure nozzle is the most commonly used type. It is designed to receive a pressurised flow of herbicide and to deliver the herbicide in a set spray pattern, which then breaks into a defined range of droplets. Other nozzle types such as the rotary atomiser, which produces a controlled droplet size, and the twin fluid nozzle, which incorporates air into the droplets, are also used.

To minimise the risk of spray drift, nozzles classed as medium or coarse, in terms of droplet size and as described in the British Crop Protection Council (BCPC) *Hand-held amenity sprayers handbook*, should be used. The classification of any nozzle can be compromised by a change in the pressure of the spraying equipment. Nozzle suppliers can provide information on droplet classification for their products. Low drift hydraulic nozzles are available. Table 4 uses BCPC terminology to describe spray quality, droplet size and drift potential.

A large range of hydraulic nozzles (spray tips) is available. The spray pattern produced by each nozzle type is termed the 'footprint'. Abrasive spray formulations or careless handling can also easily damage nozzles, so they must be regularly inspected, to ensure they are providing the specified spray pattern.

Nozzles most commonly used on boom sprayers are:

- regular flat fan.
- twin fan.
- even flat fan.
- solid (or full) cone.
- hollow cone.

Table 4 Drift potential of different spray qualities.

Spray quality	Droplet size (µm)	Drift potential
Very fine	< 119	Very high
Fine	119–216	High
Medium	217–353	Moderate
Coarse	354–464	Low
Very coarse	> 464	Very low

Each nozzle type, except the even flat fan, requires an overlap with adjacent nozzle spray patterns for uniform application.

Regular flat fan

Flat fan nozzles have an orifice that produces a narrow, elliptical spray pattern. They are normally fitted to tractor-mounted boom sprayers. When mounted on a boom to ensure correct overlap these nozzles can produce an even, overall spray distribution. When working at the correct pressure, flat fan nozzles give a fixed spray angle, the most common being 65°, 80° and 110°. The 110° angle enables a 100% overlap at the minimum boom height while narrower angles can improve spray penetration in tall crops. Even overlap is unlikely in forestry conditions, unless new planting in good farmland conditions.

Regular flat fan nozzles are generally used for herbicide or insecticide applications where deep penetration of foliage is not required.

Twin fan

This nozzle is similar in operation to a regular flat fan nozzle but applies herbicide through two orifices, producing two fan patterns – one forward in the direction of travel and the other backwards in the opposite direction to travel – which can improve spray coverage. It should be used with caution, because each nozzle sprays half the volume of a regular fan nozzle, producing smaller droplets than a regular flat fan nozzle. It is best suited to application of contact herbicides that require good spray coverage. The twin fan spray pattern improves penetration through dense foliage.

Even flat fan

The even flat fan nozzle (Figure 3) is similar to the regular flat fan nozzle but applies a more even volume of spray across the spray pattern. It is designed to apply solution in a band or narrow strip under the nozzle and does not require to be overlapped with other nozzles. As it has to be placed directly over the target tree, their use is restricted to trees under 0.5 m. The risk of over-spraying related to tree pesticide tolerance must be clearly understood.

Increasing the operating height of an even flat fan nozzle increases the effective spray width. Increasing the width of the spray band decreases the effective application rate because the same volume of spray is spread over a larger area.

Figure 3 An even flat fan nozzle.



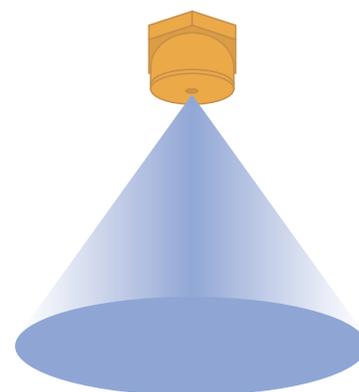
Off-centre even flat fan nozzles can be used to apply herbicide to the side of a tree which is a safer alternative to over-spraying. This enables weeding to take place when the tree is taller than 0.5 m. Because this nozzle has to be positioned to one side of the target tree, it will tend to restrict mechanised systems to treating two rows with each machine pass.

This type of nozzle can produce a solid (full) or hollow spray pattern. Solid cone nozzles are usually fitted to air-assisted crop sprayers. Some types of cone nozzle enable the operator to change the spray pattern from a hollow cone to a solid stream.

Solid (full) cone

A solid (full) cone nozzle (Figure 4) produces a circular spray pattern with the spray concentration greatest in the centre of the pattern. One- or two-piece nozzles are available, with the two-piece providing greater spray output than the one-piece. The solid cone nozzle produces a larger droplet than a hollow cone nozzle. The solid cone also produces fewer smaller droplets that may cause a drift hazard. Solid cone nozzles are usually fitted to air-assisted crop sprayers. A new range of solid cone nozzles specifically for knapsack sprayers is available. Full cone nozzles are fitted as standard equipment on many spot guns.

Figure 4 A solid (full) cone nozzle.



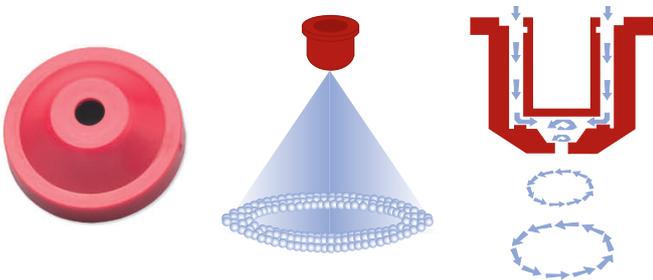
Narrow angle solid cone nozzles are better suited to applications that require spraying through deep or dense foliage than hollow cone nozzles. Wide angle solid cone nozzles may be used closer to the ground than narrow solid cone nozzles, which helps to minimise drift.

Hollow cone

The hollow cone nozzle (Figure 5) consists of a swirl plate surrounded by a swirl core with the swirl chamber between the two. Liquid passes through the spiral slots in the swirl core and into the swirl chamber where it acquires a high rotational velocity, discharging from the orifice in a hollow cone spray pattern.

These nozzles are suitable for foliar application of insecticides and fungicides, where good spray coverage of the plant or target surface is required and is widely used with knapsack sprayers. Hollow cone nozzles produce small droplets which are more likely to drift. The fine droplets produced at 3 bar pressure ensure that the nozzle is very suitable for foliar application of insecticides and fungicides.

Figure 5 A hollow cone nozzle.



Rotary atomisers

Rotary atomisers, also known as controlled droplet applicators (CDA), are designed to work at low and ultra low volume rates. The spray pattern is created by converting the herbicide flow into droplets at the edge of a spinning disc, producing a narrow range of droplet sizes. The droplet size is governed by the speed of the disc and the herbicide feed rate onto the disc.

A CDA applicator produces an umbrella type spray pattern, which maintains its spray width even when the boom height is altered. This characteristic is particularly useful when spraying over the undulating ground common on most forest sites.

CDA sprayers can be used for overall and band applications. If the rotary head is fitted with a shroud device, it can

produce an off-centre flat fan pattern and can be used to spray the side of a target tree.

Low volume spraying systems using CDA or specialist hydraulic nozzles significantly reduce water requirements and improve the logistics of managing a spraying programme. CDA and low volume hydraulic nozzles can be fitted to tractor and ATV based systems.

Because lower volumes of water are used, the herbicide and dilutant mixture in the CDA applicator contains a relatively high percentage of herbicide concentrate. Special care is required to ensure that over-application does not occur through excessive overlapping during overall spraying. Under-application and off-target contamination can take place if significant drift occurs. These points also apply to other lower volume nozzles with finer spray patterns.

SPRAYER MAINTENANCE

Sprayers must be thoroughly cleaned and maintained prior to storage. All components should be checked before and after storage. Guidance on maintenance of the main boom sprayer components is provided in Table 5.

SPRAYER TESTING

The Agricultural Engineers Association National Sprayer Testing Scheme (NSTS) tests all sprayer types and components within the spraying system. A certificate is awarded for equipment which passes the test and is valid for two years. The scheme is part of a voluntary initiative to identify if an applicator is functioning correctly, which should improve herbicide application accuracy on site. Managers and operators of mechanised systems could use this test as a control in a spraying risk assessment.

DRIFT MANAGEMENT

There are two types of airborne drift: liquid droplets and vapour. Conversion from liquid to vapour is influenced by temperature, humidity and wind, and is generally more dependent on product formulation than application method.

The following factors affect drift of liquid droplets:

- nozzle type and size;
- operating pressure;

Table 5 Boom sprayer components: key requirements for maintenance.

Components	Essential maintenance
Tank	Ensure that tank is clean, inside and out. Check for cracks and other signs of visible damage. Ensure that tank is fixed in the main frame and that any securing systems are in good order.
Pump	Check for signs of leakage and that the pump rotates without hindrance, this can be done manually or by running at low speed. Check lubrication levels, flow rates and pressure settings.
Hoses	Check for signs of cracking and splitting, particularly where the boom folds. Check connections to ensure that they do not leak. Look for signs of routine wear and tear, especially where the hose can chafe against parts of the sprayer.
Filters	Ensure that all the necessary filters are in place and that they are not damaged or blocked. Check that seals and other constituent parts are present and that the filter does not leak.
Controls	Test all controls: electrical, hydraulic or air, to ensure they are fully operational. Check for leaks.
Pressure gauge	Replace faulty pressure gauges. Contact the dealer or manufacturer if there are any doubts.
Boom	Ensure that all shock absorbers, pivot points and other moving parts operate correctly and that there is no undue wear. Test folding mechanism(s) for smooth operation. Check that the height adjusting system and break back system are working correctly. Check all the boom pipes and hoses for splits, chafing, cracks and leaks.
Anti-drip valves	Test under pressure to detect any leaks and to assess cut-off performance. Check diaphragms and valve seatings.
Nozzles	See Herbicide delivery system (page 6).
Calibration	To maintain correct application rates, calibration must be carried out at the following minimum intervals: <ul style="list-style-type: none"> • at the beginning of each season; • after every 100 ha of spraying (less in some demanding forestry situations); • after changes of tractor or tractor wheels, nozzle tips or operating pressure; • after every change of nozzle, herbicide or volume rate. <p>Maintenance needs to be carried out on a regular basis and must follow manufacturer's guidelines.</p>

- droplet size;
- sprayer design;
- weather conditions;
- sprayer operating method.

The main variables to consider when managing drift are droplet size, wind and applicator speed. Increasing operating pressure and using lower volume rates produces smaller droplets which are more prone to drift as wind or applicator speed increases. Droplet sizes of 150 microns (µm) or less pose the greatest concern, but large droplets may bounce off the target.

Guidelines to reduce drift

Before spraying:

- The operator must be trained and have an appropriate certificate of competence.

- The spraying operation should be planned to use medium spray quality where possible.
- Herbicide label guidance must be read and followed.
- The correct nozzle for the target application must be used. The size and position of the nozzles should be adjusted to achieve correct spray distribution, particularly as the growing season progresses.
- Spray additives can be used to reduce drift.
- Spraying operations should be planned to ensure adequate time to spray only during 'ideal' weather conditions, i.e. low wind speeds, avoiding days when conditions can result in drift.
- Water should be used to calibrate the sprayer to ensure the system achieves the required spray pattern.

- Guidance should be taken from Forestry Commission Practice Guide *Reducing pesticide use in forestry* (Willoughby *et al.*, 2004) and *Forests and water guidelines* (Forestry Commission, 2003).

During spraying:

- The spray must not be allowed to drift on to non-target areas. Adjustments should be made for changes in wind speed and direction.
- Spray pressure should be as low as possible and an accurate gauge must be used.
- Constant speed and pressure should be maintained, even if a spray management control system is fitted. Small increases in speed result in large increases in pressure. The delivered air and spray must be given time to penetrate the canopy.
- Spraying should not be carried out near sensitive crops or watercourses; a buffer zone should be used. A 'headland' can be created by spraying inwards with one side of the sprayer.

Buffer zones need to be 10 m wide for permanent watercourses and 20 m wide for lochs and reservoirs.

To avoid drift problems apply the correct product to the target, at the correct time with the right equipment.

CONCLUSIONS

Mechanisation of herbicide spraying operations can result in:

- lower unit costs;
- reduced operator contamination;
- improved operator ergonomics;
- improved efficiency;
- improved tree establishment.

The use of mechanised spraying systems will be influenced by:

- site and terrain conditions;
- operating costs;
- size, distribution and type of work programmes;
- availability of selected system and/or components.

Pre-season and regular maintenance is essential.

RECOMMENDATIONS

It is recommended that boom sprayers are:

- Mounted on multi-wheel drive prime movers that are guarded and suitable for forest use.
- Fitted with boom suspension and break back systems to improve performance in forestry conditions.
- Fitted with spray management systems that enable moderate changes of travelling speed to take place without affecting target volume rate application.
- Used with systems or methods to monitor the accuracy of machine travel (and the area the herbicide is applied to) across the site.
- Fitted with herbicide handling/mixing systems that reduce the risk of operator and environmental contamination.
- Used in a manner to minimise drift.
- Fitted with herbicide handling and cab systems that improve operator ergonomics.
- Tested using the Agricultural Engineers Association National Sprayer Testing Scheme.

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Further information

Information on the Agricultural Engineers Association
National Sprayer Testing Scheme (NSTS) can be obtained
from: www.nsts.org.uk

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